# Mohs scale of mineral hardness

The **Mohs scale of mineral hardness** (/moʊz/) is a qualitative ordinal scale, from 1 to 10, characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material.

*Mohs hardness kit, containing one specimen of each mineral on the ten-point hardness scale*

The scale was introduced in 1822 by the German geologist and mineralogist Friedrich Mohs, in his *Treatise on Mineralogy*;[1][2] it is one of several definitions of hardness in materials science, some of which are more quantitative.[3]

The method of comparing hardness by observing which minerals can scratch others is of great antiquity, having been mentioned by Theophrastus in his treatise *On Stones*, c. 300 BC, followed by Pliny the Elder in his *Naturalis Historia*, c. AD 77.[4][5][6] The Mohs scale is useful for identification of minerals in the field, but is not an accurate predictor of how well materials endure in an industrial setting – *toughness*.[7]

## Use

Despite its lack of precision, the Mohs scale is relevant for field geologists, who use the scale to roughly identify minerals using scratch kits. The Mohs scale hardness of minerals can be commonly found in reference sheets.

Mohs hardness is useful in milling. It allows assessment of which kind of mill will best reduce a given product whose hardness is known.[8] The scale is used at electronic manufacturers for testing the resilience of flat panel display components (such as cover glass for LCDs or encapsulation for OLEDs), as well as to evaluate the hardness of touch screens in consumer electronics.[9]

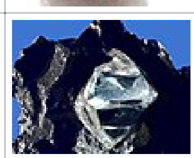
## Minerals

The Mohs scale of mineral hardness is based on the ability of one natural sample of mineral to scratch another mineral visibly. The samples of matter used by Mohs are all different minerals. Minerals are chemically pure solids found in nature. Rocks are made up of one or more minerals. As the hardest known naturally occurring substance when the scale was designed, diamonds are at the top of the scale. The hardness of a material is measured against the scale by finding the hardest material that the given material can scratch, or the softest material that can scratch the given material. For example, if some material is scratched by apatite but not by fluorite, its hardness on the Mohs scale would be between 4 and 5.[10]

"Scratching" a material for the purposes of the Mohs scale means creating non-elastic dislocations visible to the naked eye. Frequently, materials that are lower on the Mohs scale can create microscopic, non-elastic dislocations on materials that have a higher Mohs number.

While these microscopic dislocations are permanent and sometimes detrimental to the harder material's structural integrity, they are not considered "scratches" for the determination of a Mohs scale number.[11]

The Mohs scale is a purely ordinal scale. For example, corundum (9) is twice as hard as topaz (8), but diamond (10) is four times as hard as corundum. The table below shows the comparison with the absolute hardness measured by a sclerometer, with pictorial examples.[12][13]

| Mohs hardness | Mineral | Chemical formula | Absolute hardness[14] | Image |
|---|---|---|---|---|
| **1** | Talc | $Mg_3Si_4O_{10}(OH)_2$ | 1 |  |
| **2** | Gypsum | $CaSO_4{\cdot}2H_2O$ | 2 |  |
| **3** | Calcite | $CaCO_3$ | 14 |  |
| **4** | Fluorite | $CaF_2$ | 21 |  |
| **5** | Apatite | $Ca_5(PO_4)_3(OH^-,Cl^-,F^-)$ | 48 |  |
| **6** | Orthoclase feldspar | $KAlSi_3O_8$ | 72 |  |
| **7** | Quartz | $SiO_2$ | 100 |  |
| **8** | Topaz | $Al_2SiO_4(OH^-,F^-)_2$ | 200 |  |
| **9** | Corundum | $Al_2O_3$ | 400 |  |
| **10** | Diamond | C | 1500 |  |

On the Mohs scale, a streak plate (unglazed porcelain) has a hardness of approximately 7.0. Using these ordinary materials of known hardness can be a simple way to approximate the position of a mineral on the scale.[15]

## Intermediate hardness

The table below incorporates additional substances that may fall between levels:[16]

| Hardness | Substance or mineral |
|---|---|
| 0.2–0.3 | caesium, rubidium |
| 0.5–0.6 | lithium, sodium, potassium, candle wax |
| 1 | talc |
| 1.5 | gallium, strontium, indium, tin, barium, thallium, lead, graphite, ice[17] |
| 2 | hexagonal boron nitride,[18] calcium, selenium, cadmium, sulfur, tellurium, bismuth, gypsum |
| 2–2.5 | halite (rock salt), fingernail,[19] mica[20] |
| 2.5–3 | gold, silver, aluminium, zinc, cryolite, lanthanum, cerium, jet |
| 3 | calcite, copper, arsenic, antimony, thorium, dentin, chalk[21] |
| 3.5 | platinum, azurite |
| 4 | fluorite, iron, nickel |
| 4–4.5 | ordinary steel |
| 5 | apatite (tooth enamel), zirconium, palladium, obsidian (volcanic glass) |
| 5.5 | beryllium, molybdenum, hafnium, glass, cobalt |
| 6 | orthoclase, titanium, manganese, germanium, niobium, uranium, rhodium |
| 6–7 | fused quartz, iron pyrite, silicon, ruthenium, iridium, tantalum, opal, peridot, tanzanite, rhodium, jade, garnet,[21] pyrite[21] |
| 7 | osmium, quartz, rhenium, vanadium |
| 7.5–8 | emerald, beryl, zircon, tungsten, spinel |
| 8 | topaz, cubic zirconia, hardened steel, spinel[22] |
| 8.5 | chrysoberyl, chromium, silicon nitride, tantalum carbide |
| 9 | corundum (includes sapphire and ruby), tungsten carbide, titanium nitride, aluminium oxide |
| 9–9.5 | silicon carbide (carborundum), tantalum carbide, zirconium carbide, alumina, beryllium carbide, titanium carbide, aluminum boride, boron carbide.[a][23][24] |
| 9.5–near 10 | boron, boron nitride, rhenium diboride (*a*-axis),[25] stishovite, titanium diboride, moissanite (crystal form of silicon carbide), boron carbide[21] |
| 10 | diamond, carbonado |

## Comparison with Vickers scale

Comparison between Mohs hardness and Vickers hardness:[26]

| Mineral name | Hardness (Mohs) | Hardness (Vickers) (kg/mm$^2$) |
|---|---|---|
| Graphite | 1–2 | $VHN_{10}$ = 7–11 |
| Tin | 1.5 | $VHN_{10}$ = 7–9 |
| Bismuth | 2–2.5 | $VHN_{100}$ = 16–18 |
| Gold | 2.5 | $VHN_{10}$ = 30–34 |
| Silver | 2.5 | $VHN_{100}$ = 61–65 |
| Chalcocite | 2.5–3 | $VHN_{100}$ = 84–87 |
| Copper | 2.5–3 | $VHN_{100}$ = 77–99 |
| Galena | 2.5 | $VHN_{100}$ = 79–104 |
| Sphalerite | 3.5–4 | $VHN_{100}$ = 208–224 |
| Heazlewoodite | 4 | $VHN_{100}$ = 230–254 |
| Carrollite | 4.5–5.5 | $VHN_{100}$ = 507–586 |
| Goethite | 5–5.5 | $VHN_{100}$ = 667 |
| Hematite | 5–6 | $VHN_{100}$ = 1,000–1,100 |
| Chromite | 5.5 | $VHN_{100}$ = 1,278–1,456 |
| Anatase | 5.5–6 | $VHN_{100}$ = 616–698 |
| Rutile | 6–6.5 | $VHN_{100}$ = 894–974 |
| Pyrite | 6–6.5 | $VHN_{100}$ = 1,505–1,520 |
| Bowieite | 7 | $VHN_{100}$ = 858–1,288 |
| Euclase | 7.5 | $VHN_{100}$ = 1,310 |
| Chromium | 8.5 | $VHN_{100}$ = 1,875–2,000 |

## See also

- Brinell scale

- Geological Strength Index
- Hardnesses of the elements (data page)
- Knoop hardness test
- Meyer hardness test
- Pencil hardness
- Rockwell scale
- Rosiwal scale
- Scratch hardness
- Superhard material

# Explanatory notes

a. *Carbides of some metals and semi-metals are quite hard (as well as brittle); carbides of tungsten (WC), tantalum (TaC), zirconium (ZrC), beryllium ($Be_2C$), titanium (TiC), silicon (SiC), and boron ($B_4C$) all have Mohs hardness levels between 9 and 10.*[23][24]

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## Further reading

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